Preliminary Results of the SWAC - TES Analysis Project

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Innovative Energy Systems Workshop

Honolulu – March 19, 2003

Outline

- Overview of Thermal Energy Storage (TES)
  - Types of TES and Applications in District Cooling
- The SWAC-TES Analysis Project
  - Concept and Objective
  - Tasks
  - Results to-date
- Moving SWAC to Commercial Reality
- Summary and Conclusions

Terminology

- CHW - Chilled Water
- CHWS/R - Chilled Water Supply / Return
- CT - Combustion Turbine
- CTIC - Combustion Turbine Inlet Cooling
- DC - District Cooling
- DSM - Demand-Side Management
- LTF - Low Temperature Fluid
- SWAC - Sea Water Air-Conditioning
- TES - Thermal Energy Storage

TES Technologies

- Technologies include:
  - Latent Heat TES (ice storage) - water is frozen in off-peak times and melted for cooling during peak times.
  - Sensible Heat TES (stratified chilled water (CHW) and low temperature fluid (LTF) storage) - water or fluid is chilled off-peak, stored in an insulated tank, and used for cooling during peak times.
- Each TES technology has inherent advantages and limitations.
- Understanding those attributes is important to applying TES for maximum value.

TES Applications

- TES is already widely used in large commercial, industrial, and institutional cooling systems.
- Various types of DC applications use TES:
  - Private Industry
  - Universities and Colleges
  - Hospital and Medical Facilities
  - Other Government Facilities
  - District Cooling Utility Systems
  - Combustion Turbine Inlet Cooling
- TES reduces operating and (at times) capital cost

State of Hawaii – Cool Solutions Study: Integration of TES with SWAC Systems

- Builds on earlier SWAC Feasibility Report
- Objective
  - To ultimately commercialize SWAC or hybrid SWAC-TES systems in Hawaii, with potential technology export to other areas
- Description – Hybrid SWAC-TES allows:
  - Larger peak loads served by SWAC piping, or
  - Smaller SWAC piping to meet a peak load.
  - Improved economics and capture of benefits

State of Hawaii – Cool Solutions Study: Integration of TES with SWAC Systems

Work Plan Activities / Tasks:

1. Review and Analysis of earlier SWAC report
2. Literature Search: TES applicable to SWAC
3. Economic Analysis
4. Preliminary Design
5. Marketing Plan
6. Financing Mechanisms
7. Innovative Energy Systems Workshop
8. Final Report

Task 1 – Review and Analysis of the Earlier SWAC Feasibility Report

- Review SWAC report and verify assumptions related to DC and TES
- Identify potential SWAC systems that benefit from incorporating TES
- Summary, conclusions, recommendations

Task completed: February 2003

Task 1 – Review and Analysis of the Earlier SWAC Feasibility Report

Results:

- Assumptions generally valid & appropriate
- Most SWAC systems benefit from TES
- Summary, conclusions, recommendations
  - SWAC analysis is quite conservative
  - Can reduce contingency for SWAC
  - Incorporate personnel cost savings of DC
  - Pursue SWAC DC
  - Pursue SWAC DC with TES

Task 2 – Literature Search and Analysis of TES Applicable to SWAC

- Literature search for TES suited to SWAC
  - Handbooks and Design Guides on TES and DC (6 sources from ASHRAE, EPRI, Europe)
  - Specific analyses and case studies (30 papers)
  - TES supplier info / communications (8 firms)
- Analyzed, evaluated, and summarized
- Conclusions and recommendations

Task completed: February 2003

TES in Private Industry

TES Owner/Operator	TES Type	Ton-hours
3M - 3 locations (MN, MO, TX)	CHW	51,200
Chrysler Motors - Auburn Hills, MI	CHW	68,000
Exxon - Houston, TX	CHW	10,000
General Motors - 2 locations (MI, OK)	CHW / LTF	81,500
Homesavings of America - Irvindale, CA	Ice	13,600
Honeywell - 3 locations (AZ, MN, TX)	CHW	29,800
IBM - 2 locations (KY, MN)	CHW	58,000
McDonnell Douglas - Long Beach, CA	CHW	17,000
Pratt & Whitney - North Haven, CT	CHW	20,000
Shell - Houston, TX	CHW	38,500
State Farm - 4 locations (AZ, GA, IL, TX)	CHW	125,600
Texas Instruments - 3 locations (all in TX)	CHW	102,000
Toyota - 2 locations (IN, KY)	CHW	164,500
Via Parque Shopping - Rio de Janeiro, Brazil	CHW	13,200

CHW TES in Private Industry

(photo compliments of Chicago Bridge & Iron Co.)

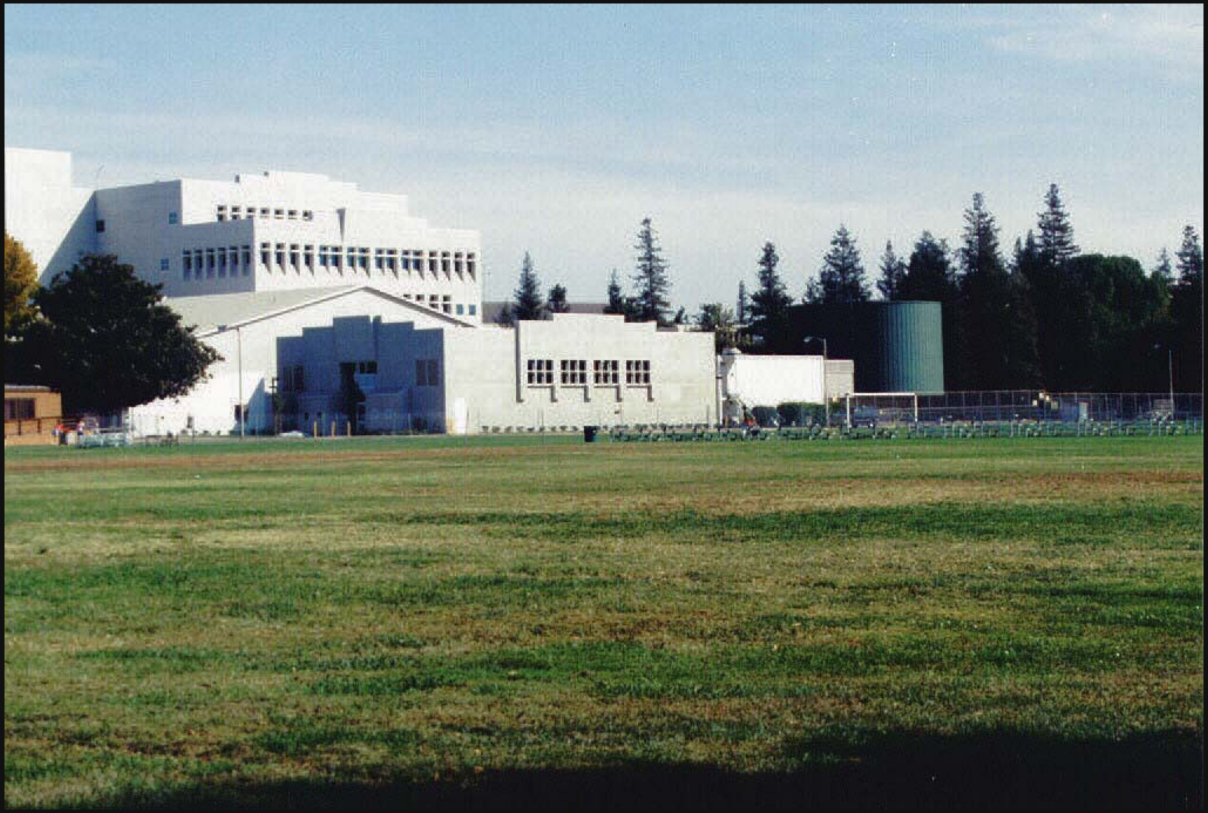
- 3M - Maplewood, MN (commissioned in 1992)
- 32,000 ton-hours, with 40 / 55 ºF CHW supply / return temperatures
- 110 ft diameter x 58 ft high (4,123,000 gals)
- Subsequently, two more CHW TES tanks sited at other 3M facilities

TES in Universities and Colleges

TES Owner/Operator	TES Type	Ton-hours
Arizona State U - Phoenix, AZ	CHW	54,000
California State U - 14 campuses in CA	CHW / HW	281,100
Cornell U - Ithaca, NY	CHW	38,000
Florida State U - Tallahassee, FL	CHW	16,000
New Mexico State U - Las Cruces, NM	CHW	20,000
North Harris College - Houston, TX	CHW	15,000
Stanford U - Palo Alto, CA	Ice	93,000
Texas A&M U - Corpus Christi, TX	CHW	11,800
U of Akron - Akron, OH	CHW	28,400
U of California - 6 campuses in CA	CHW	228,100
U of Pennsylvania - Philadelphia, PA	Ice	22,000
U of Texas - El Paso, TX	CHW	30,000
U of Virginia - Charlottesville, VA	CHW / LTF	16,200
Washington State U - Pullman, WA	CHW	17,800
Planned - Northeast U.S. university	LTF	50,000

CHW TES at a University

(photo compliments of Chicago Bridge & Iron Co.)



- California State University - Sacramento, CA (commissioned in 1991)
- 12,300 ton-hours, with 42 / 62 ºF CHW supply / return temperatures
- 62 ft diameter x 48 ft high (1,084,000 gals)
- Subsequently, a dozen more CHW TES sited at other CSU campuses

TES in Hospital and Medical Facilities

TES Owner/Operator	TES Type	Ton-hours
Athens Regional Medical Center - Athens, GA	Ice	5,000
City of Hope National Med Center - Duarte, CA	CHW	18,200
Fairview State Hospital - Costa Mesa, CA	CHW / LTF	8,200
Lanterman State Hospital - Pomona, CA	CHW / LTF	10,700
Penn State Hershey Med Center - Hershey, PA	CHW	12,500
St. Mary's Hospital - West Palm Beach, FL	CHW	13,900
St. Joseph's Medical Center - Stockton, CA	CHW	5,400
Texas State Hospital - Terrell, TX	CHW	7,000
U. of Maryland Med System - Baltimore, MD	Ice	9,600
U.S. VA Med Center - 2 sites, Dallas & Houston	CHW	54,600

TES in Other Government Facilities

TES Owner/Operator	TES Type	Ton-hours
Bayfront Arts & Science Pk - Corpus Christi, TX	CHW	13,800
Brookhaven National Laboratory - Upton, NY	CHW	20,000
Cincinnati Art Museum	Ice	2,800
D/FW International Airport - Dallas/Ft.Worth, TX	LTF	90,000
DuPage County Complex - Wheaton, IL	CHW	10,700
Los Angeles Dept. of Corrections - 2 sites in CA	CHW	16,000
Midway Airport - Chicago, IL	Ice	14,000
Reagan National Airport - Washington, DC	CHW	22,000
San Antonio Internat’l Airport - San Antonio, TX	CHW	4,000
Sonoma County Complex - Santa Rosa, CA	CHW	9,600
U.S. Gen’l Services Admin - Laguna Niguel, CA	CHW	12,000

TES in District Cooling Utilities

TES Owner/Operator	TES Type	Ton-hours
Chauffage Urbain Prodith - Lyon, France	Ice	8,500
Climaespaco - Lisbon, Portugal	CHW	39,800
District Cooling St. Paul - 2 sites in St. Paul, MN	CHW	65,400
Entergy Thermal NORMC - New Orleans, LA	Ice	52,000
Exelon Thermal Tech's - 3 sites in Chicago, IL	Ice	259,000
National Central Cooling - 4 sites in Dubai, UAE	CHW	60,000
Norrenergi AB - Stockholm, Sweden	CHW	17,000
Northwind Boston - Boston, MA	Ice	32,000
Northwind Windsor - Windsor, Ontario, Canada	Ice	8,500
OUCooling - Orlando, FL	CHW / LTF	160,000
Public Service Co. of Colorado - Denver, CO	Ice	37,500
Reedy Creek (Disney World) - Orlando, FL	CHW	57,000
Tenaga Nasional Berhad - Bangi, Malaysia	CHW	26,000
The Energy Network - Hartford, CT	CHW	20,000
Trigen Energy - 5 sites (IL, MI, NJ, OK, Mexico)	CHW / LTF	229,200

LTF TES at a District Cooling Utility

(photo compliments of Chicago Bridge & Iron Co.)

- Trigen-Peoples District Energy - Chicago, IL (commissioned in 1994)
- 123,000 ton-hours, with 30 / 54 ºF LTF supply / return temperatures
- 127 ft diameter x 90 ft high (8,528,000 gals)
- Subsequently, three more CHW / LTF TES sited at other Trigen plants

TES in Combustion Turbine Inlet Cooling (CTIC)

- CT power drops in hot weather, when needed most.
- Cooling CT inlet air can often increase power by 20% to 30%, at low capital cost per kW.

TES Owner/Operator	TES Type	Ton-hours
Calpine Clear Lake Cogen - Pasadena, TX	CHW	107,000
Climaespaco - Lisbon, Portugal	CHW	39,800
Lincoln Electric System, Lincoln, NE	Ice	165,000
Reedy Creek (Disney World) - Orlando, FL	CHW	57,000
Texaco Cogeneration, San Ramon, CA	Ice	14,800
Trigen-Peoples District Energy - Chicago, IL	LTF	123,000

Inherent Characteristics of TES

	Ice	CHW	LTF
Volume	good	poor	fair
Footprint	good	fair	good
Modularity	excell	poor	good
Economy-of-Scale	**poor**	**excell**	**good**
Energy Efficiency	fair	excell	good
Low Temp Capability	good	poor	excell
Ease of Retrofit	**poor**	**excell**	**fair**
Rapid Discharge Capability	poor	good	good
Simplicity and Reliability	fair	excell	good
Site Remotely from Chillers	**poor**	**excell**	**excell**
Dual-use as Fire Protection	poor	excell	poor
Suited to Recharge via SWAC	**poor**	**excell**	**poor**

Task 2 – Literature Search and Analysis of TES Applicable to SWAC

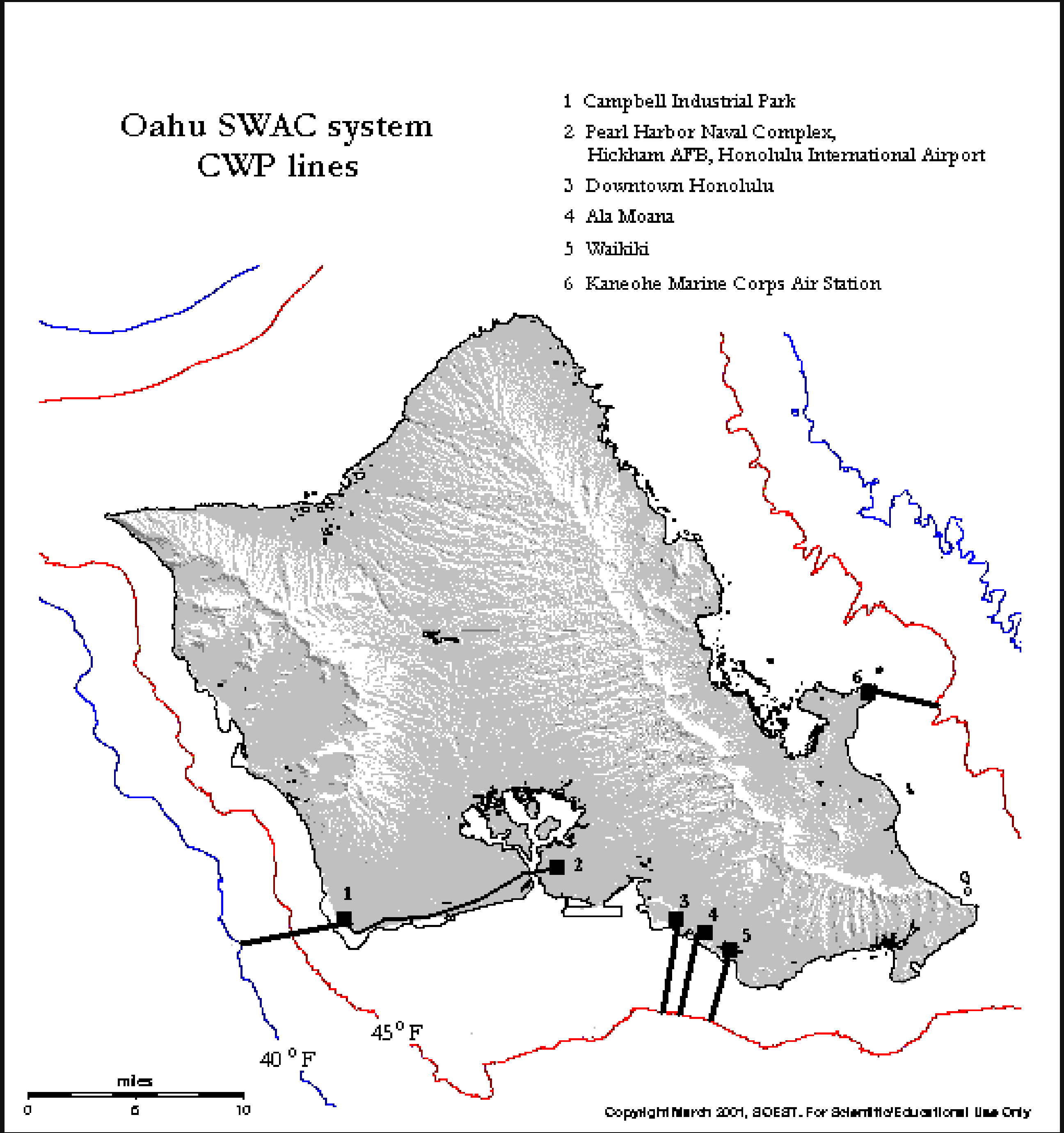
Results:

- All TES (Ice, CHW, LTF) used in DC
- CHW TES most often used in large DC
  - Economy-of-scale
  - Ease of Retrofit (with existing chillers)
  - Can site remotely from chiller plants
- SWAC temps too warm for ice or LTF TES
- CHW TES generally best fit for SWAC DC
- All TES can be used, case-specific.

Task 3 – Economic Analysis of Hybrid SWAC-TES Systems

- SWAC-TES capital costs
- SWAC-TES O&M costs
- Comparative life cycle cost vs conventional
- Revenue requirements and risks
- Identify and prioritize candidate systems

Projected completion: April 2003


Oahu SWAC system
CWP lines
1 Campbell Industrial Park
2 Pearl Harbor Naval Complex, Hickham AFB, Honolulu International Airport
3 Downtown Honolulu
4 Ala Moana
5 Waikiki
6 Kaneohe Marine Corps Air Station
45 °F
40 °F
miles
0
5
10
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Task 3 – Economic Analysis Preliminary Results – TES Case 1

<u>Honolulu Waterfront - Kakaako - W. Waikiki</u>

- Integrate 3 individual SWAC DC systems
- Add CHW TES, centrally located
- Eliminate the SW piping to Kakaako
- 24,025 T peak is served by 16,775T SWAC plus 7,250 T (50,750 T-hrs) of CHW TES

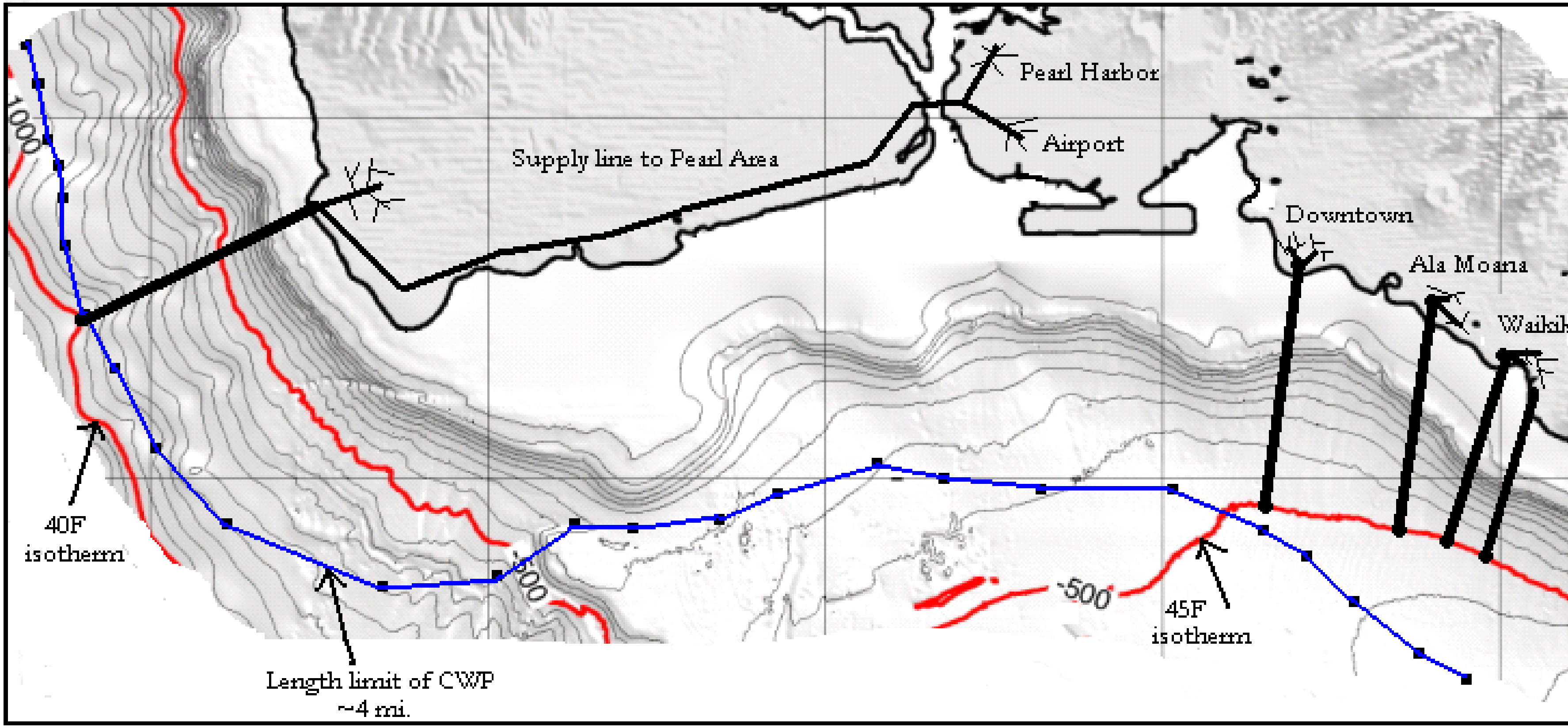
- *TES reduces cost of water over book life by 10 to 15% vs. non-TES base cases*

Task 3 – Economic Analysis Preliminary Results – TES Case 2

E. Waikiki - U of Hawaii-Manoa

- Add CHW TES, at UHM campus
- Significantly reduce CHW piping to UHM
- Incrementally reduce SW piping
- 7,800 T peak is served by ~6,900T SWAC plus ~900 T (~6,000 T-hrs) of CHW TES

- *TES reduces cost of water over book life by ~12% vs. non-TES base case*



Pearl Harbor
Airport
Supply line to Pearl Area
Downtown
Ala Moana
Waikiki
1000
40F
isotherm
-500
-500
45F
isotherm
Length limit of CWP
~4 mi.

Task 3 – Economic Analysis of Hybrid SWAC-TES Systems

<u>Promising candidate SWAC-TES systems:</u>

- S. Shore Oahu – Honolulu-Kakaako-Waikiki
- Kakaako – shopping-hotels-new UHMRC
- W. Shore Oahu – new development-industry-future CTs (w/ deeper, colder SW)
- Large systems, w/ economy-of-scale)
- Redundant systems, w/ multi-pipes and TES (plus chillers)

<u>Best candidates:</u> will have offsets from avoided capital investment in conventional systems (i.e. new construction; but also, expansions or chiller plant rehabs or replacements)

Task 4 – Preliminary Design of Typical Hybrid SWAC-TES System

- Develop preliminary facility design for the most promising SWAC-TES system
- Identify major components and subsystems
- Provide system layout diagram
- Develop construction timetable

Projected completion: April 2003

Task 5 – Development of Marketing Plan for SWAC-TES Systems in Hawaii

- Identify key ("anchor") and other potential cooling customers
  - Identify individual customer needs
  - Identify and quantify system benefits
- Identify all stakeholders
- Market the concept and its benefits to all stakeholders

Task 5 – Development of Marketing Plan for SWAC-TES Systems in Hawaii

- Market concept/benefits to all stakeholders
  - Customers (economy, reliability, flexibility, focus)
  - Engineers (must educate and familiarize)
  - Community (economy; coordination / traffic issues)
  - General public (economy and environment)
  - Government (meet mandates; lowers oil risks)
  - Local authorities (infrastructure, jobs, franchise fees)
  - Local electric utility (DSM and CT Inlet Cooling)
  - Auxiliary service users (new or improved options)
  - Equipment suppliers and contractors (business)
  - Investors (financial rewards, growth potential)

Task 6 – Possible Financing Mechanisms for Hybrid SWAC-TES Systems

- Identify, evaluate, and discuss potential financing mechanisms
- DC development via private, public, and public-private partnership means
  - Equity investment
  - Loans
  - Tax-exempt bonds
  - Energy efficiency grants
  - Demand-Side Management incentives
  - Performance contracting / outsourcing

Task 7 – Innovative Energy Systems Workshop in Honolulu, March 2003

- Assist in workshop planning
- Present preliminary results
- Participate in expert panel discussions
- Collate applicable workshop info
- Summarize info for use in Final Report

Task 8 – Final Report Preparation and Submittal

- Produce Draft Report
- Incorporate Hawaii DBEDT comments
- Produce Final Report

Projected completion: June 2003

Moving SWAC to Commercial Reality

- Major barriers exist
  - Perceptions of “new” concepts and technology
  - Starting any new DC business is difficult
  - SWAC requires even more up-front capital
  - Demands a long-term outlook / investment
  - Timing and logistics of creating “critical mass” of customers
  - A committed developer (private and/or public)

Moving SWAC to Commercial Reality

- But there is much reason for optimism
  - Numerous recent DC system development successes
  - Unique resources and opportunities in Hawaii
  - Proven technologies, talent, know-how
  - Energy and environmental mandates; oil risks
  - Positive economics, improved further by TES
  - Private and public interest in development

Summary

- SWAC has enormous potential benefits
- SWAC long been used, via harbor water:
  - Scandinavian DC systems
  - Halifax, Nova Scotia
- Deep Lake Cooling, via Hawaiian technology
  - 20,000 Ton DC system at Cornell U (2001)
  - 50,000 Ton DC system in Toronto (starting 2003)
- Hawaii has unique resources and potential
  - Access to adjacent deep, cold sea water
  - Developed and mature local technology and talent
  - Over 100,000 Tons of potential SWAC DC load
  - Mitigation of imported fuel and associated risks

Summary and Conclusions

- TES is a natural adjunct to SWAC DC systems
- TES long been used in DC systems:
  - Reduces operating energy costs
  - Reduces installed chiller plant capacity and capital cost
- CHW TES best suited to SWAC DC systems
  - Economy-of-scale, ease of retrofit, siting flexibility
  - Matched to available SWAC temperatures
- Preliminary results of hybrid SWAC-TES analyses
  - Applicable to most potential Hawaiian SWAC systems
  - 10 to 15% reduction in cooling cost vs non-TES SWAC
  - Improved economics increase likelihood of realization

Recommendations

- Identify and address all significant barriers
  - Those common to typical DC developments
  - Those specific to SWAC DC
  - Those specific to Hawaii
  - Those specific to individual developments / customers
- Incorporate TES in SWAC to improve economics
- Market benefits of SWAC DC to all stakeholders
  - Customers, community, general public, government, local authorities, local utility, auxiliary service users, suppliers & contractors, and developers

The benefits are much too great

not to persevere and turn the vision into a reality.